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Baba

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(54) **COMPRESSOR AND AIR CONDITIONER**

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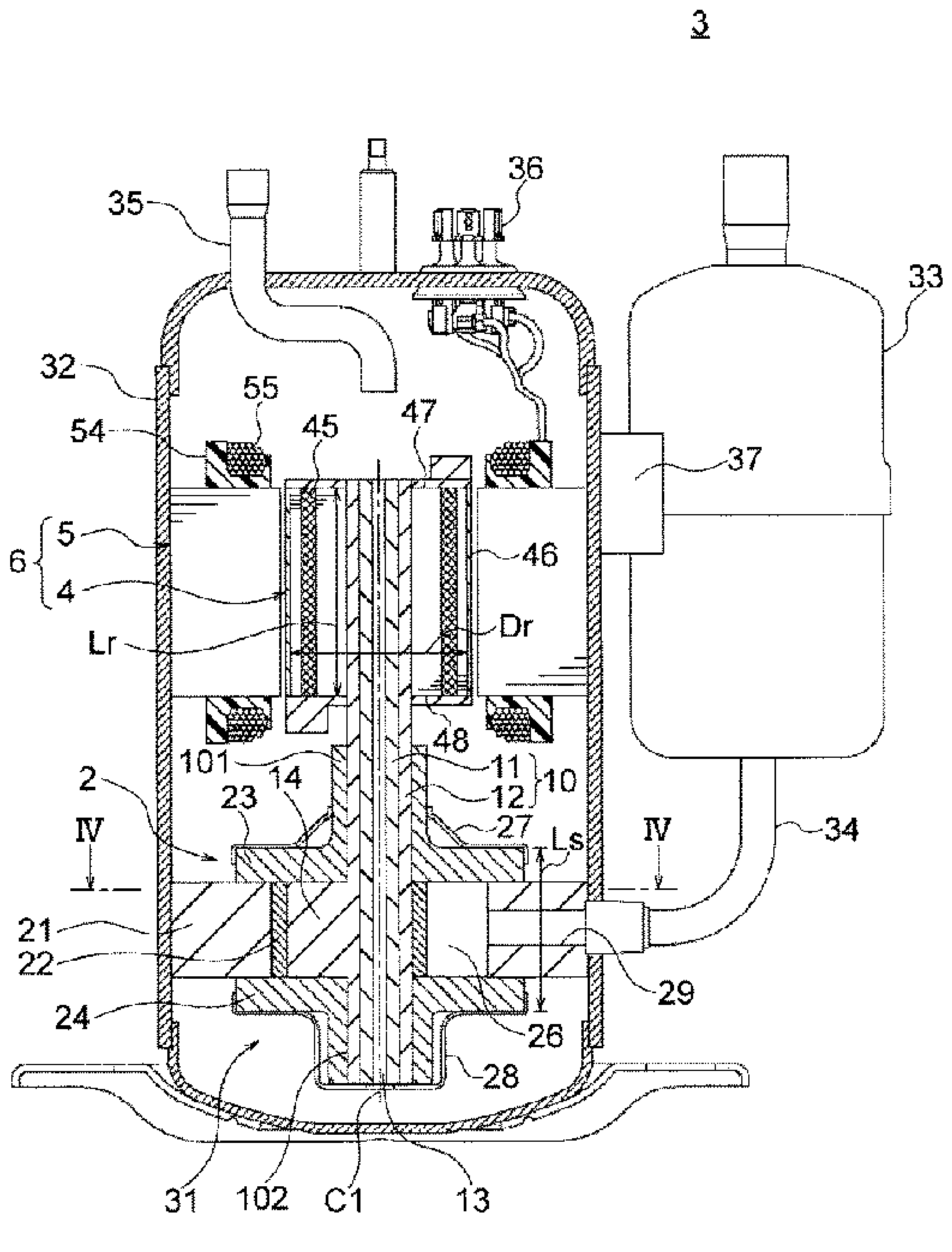
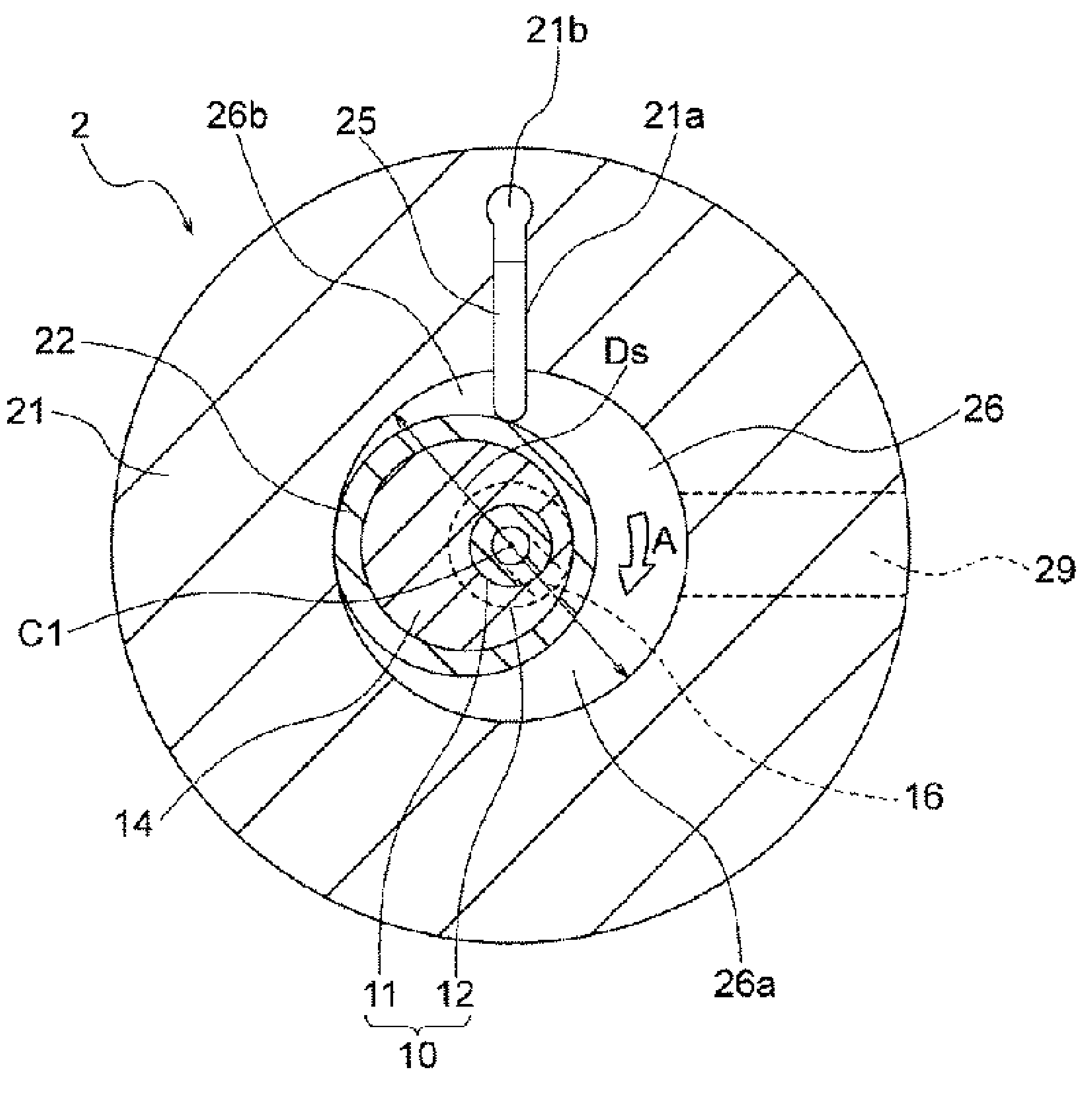
(57) **ABSTRACT**

A compressor includes a motor, a compression mechanism portion driven by the motor, and a rotation shaft connecting the motor and the compression mechanism portion. At least a part of the rotation shaft is composed of a material having a higher Young's modulus than that of cast iron, and having a higher thermal conductivity than that of cast iron.

13 Claims, 8 Drawing Sheets





(51) **Int. Cl.**

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F04C 18/356	(2006.01)
F04C 29/00	(2006.01)
F04C 23/00	(2006.01)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
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See application file for complete search history.

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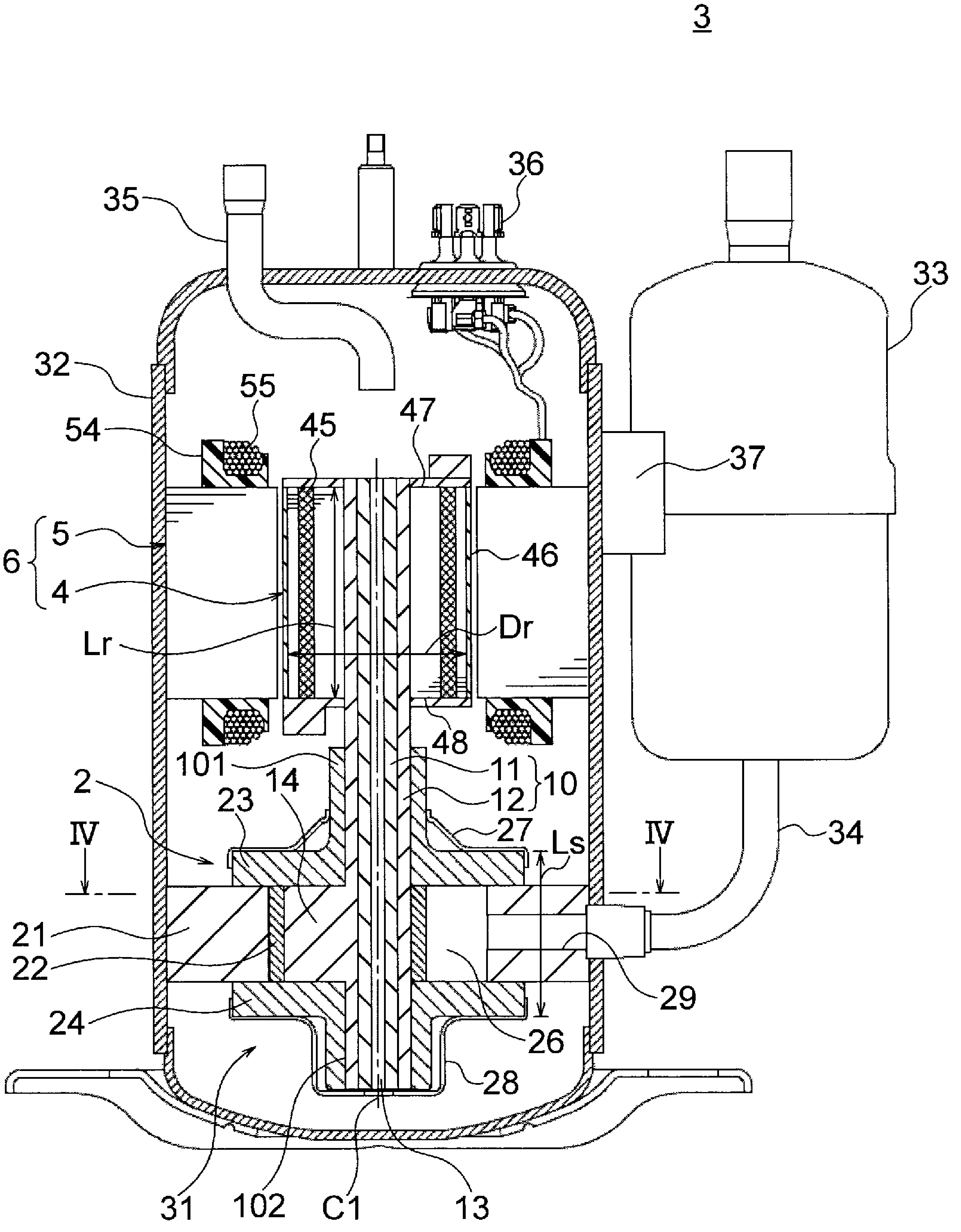
FIG. 1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12
10
2
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IV
Ls
IV
34
21
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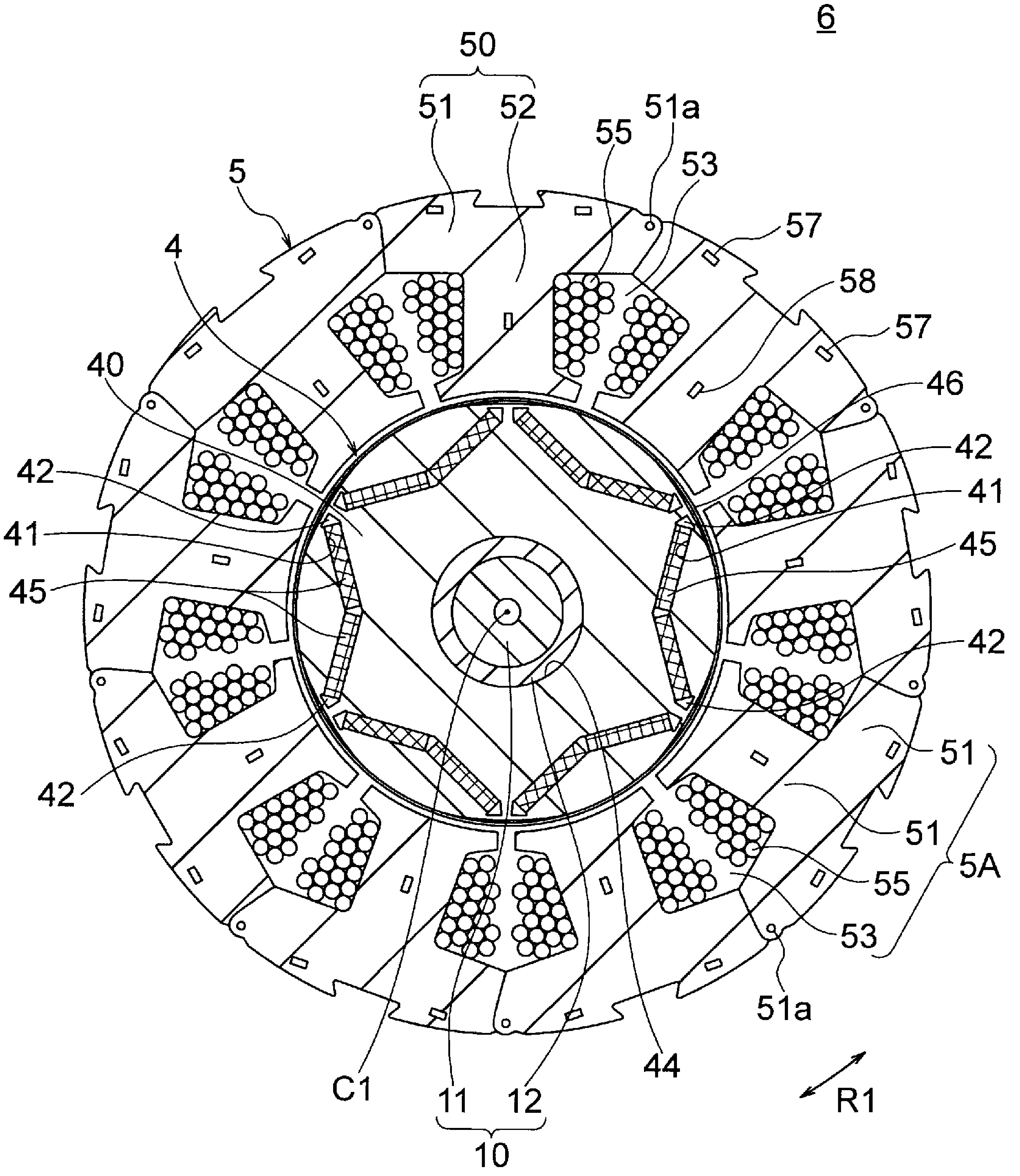
29
24
26
28
31
102
C1
13

FIG. 2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C1
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R1
10

FIG. 3

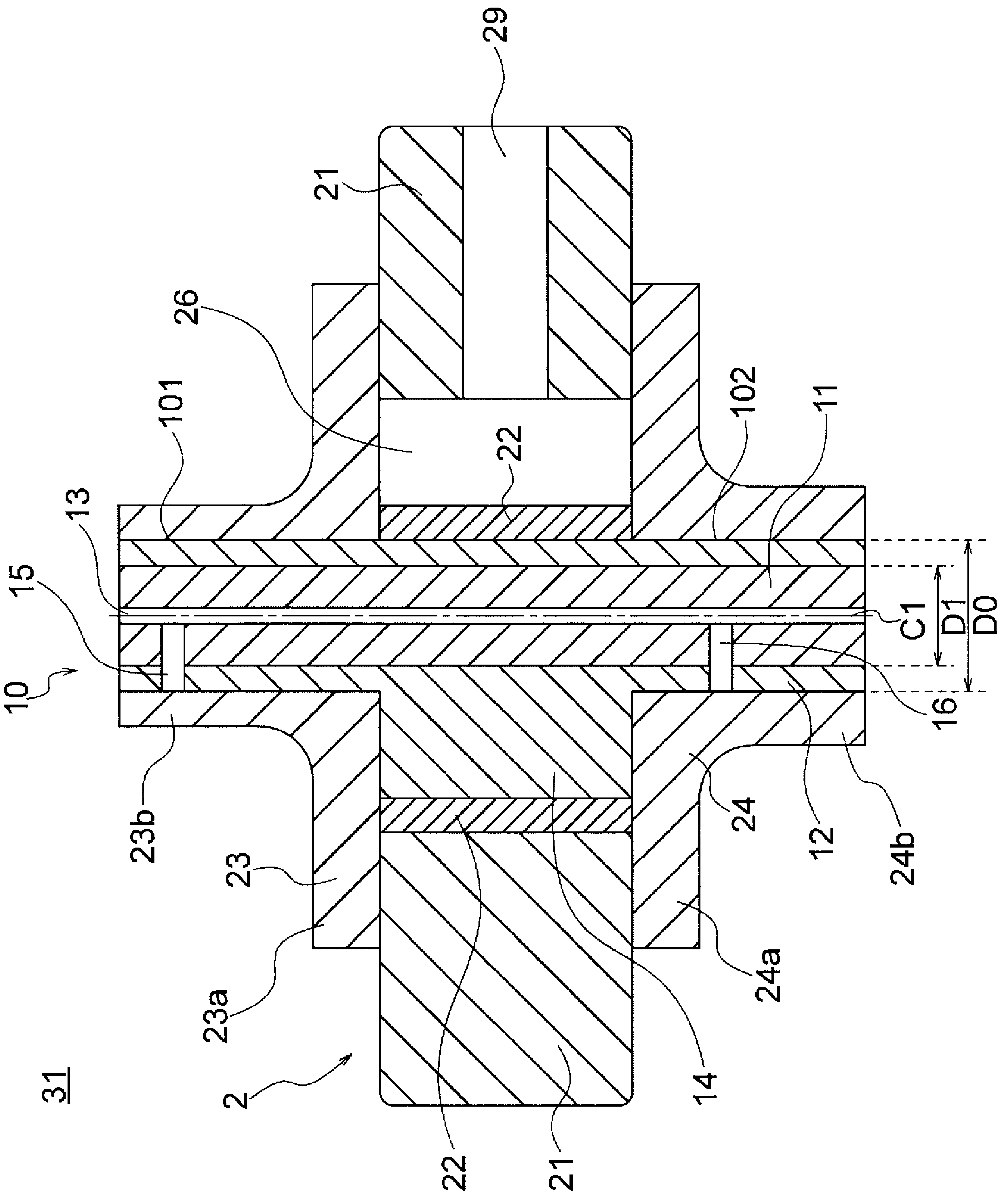
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FIG. 4

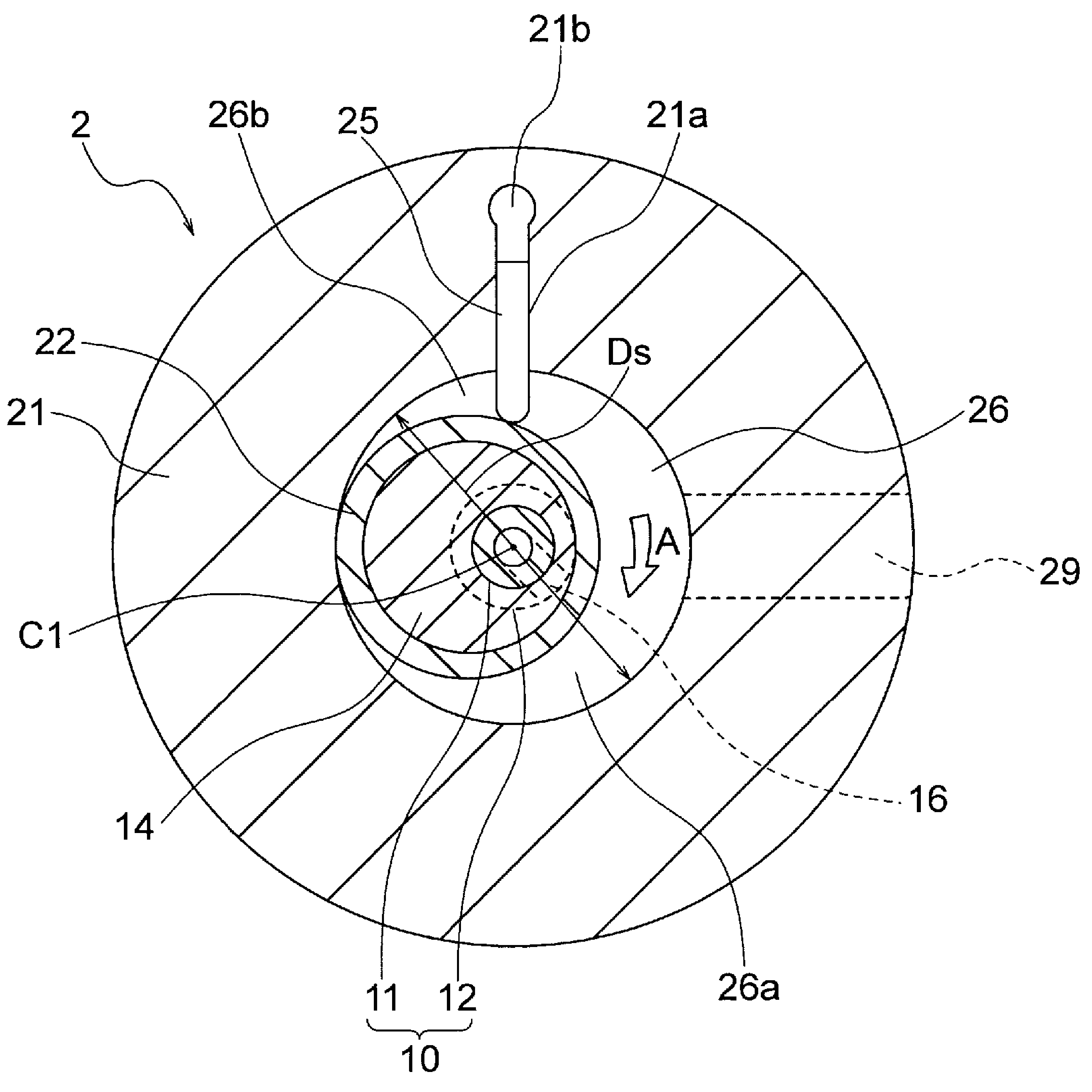
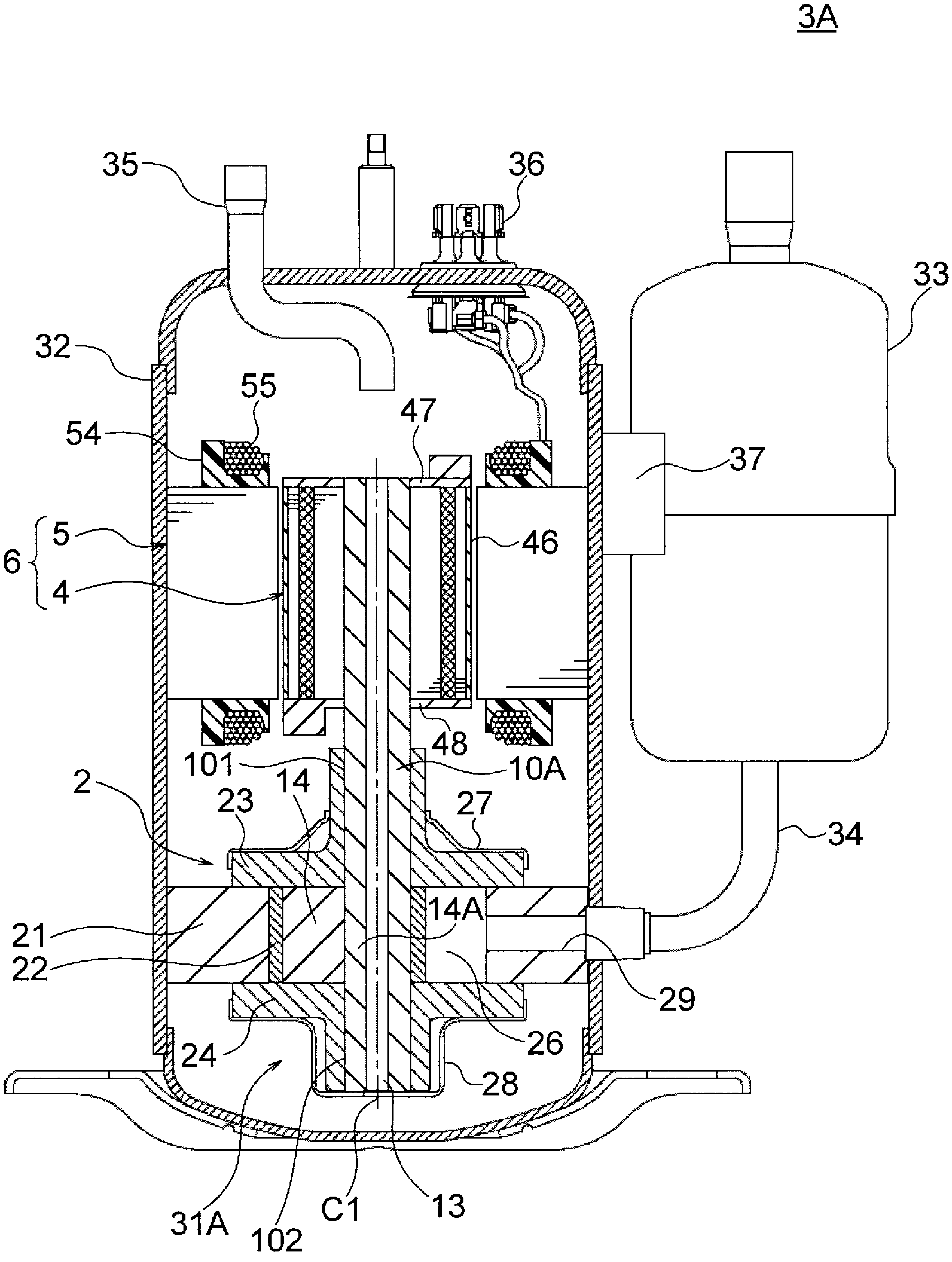


FIG. 5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24
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31A
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C1
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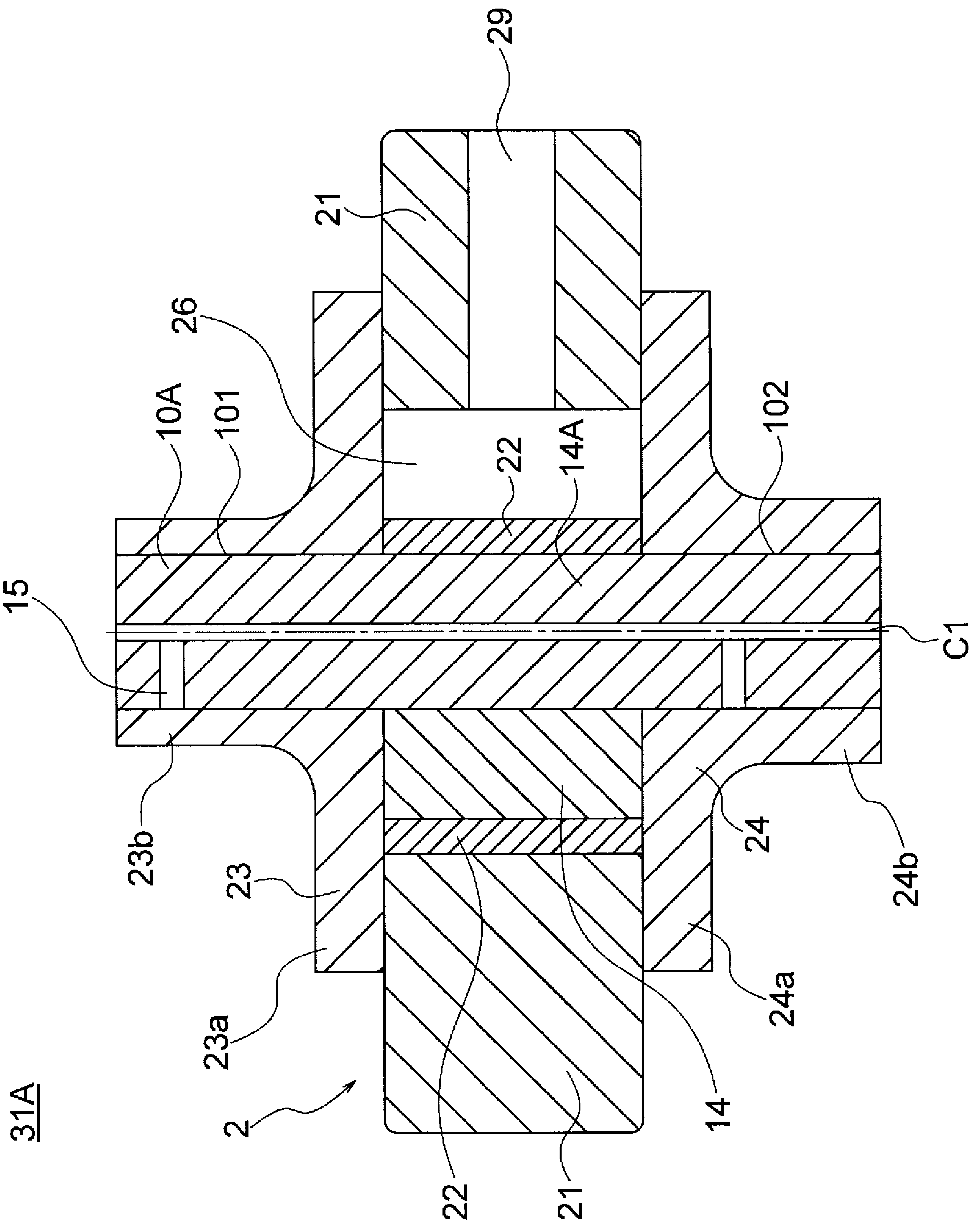
34

FIG. 6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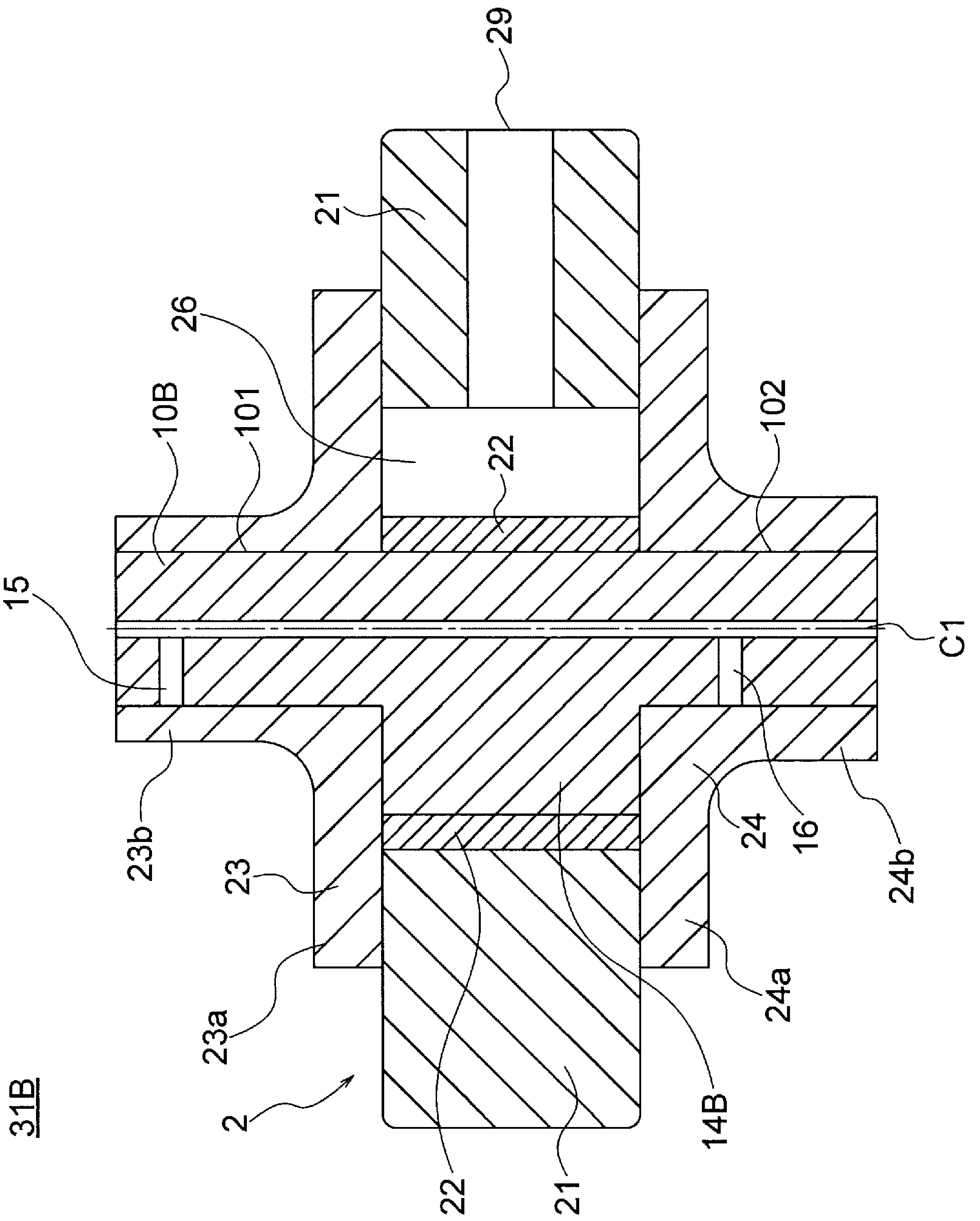
21

FIG. 7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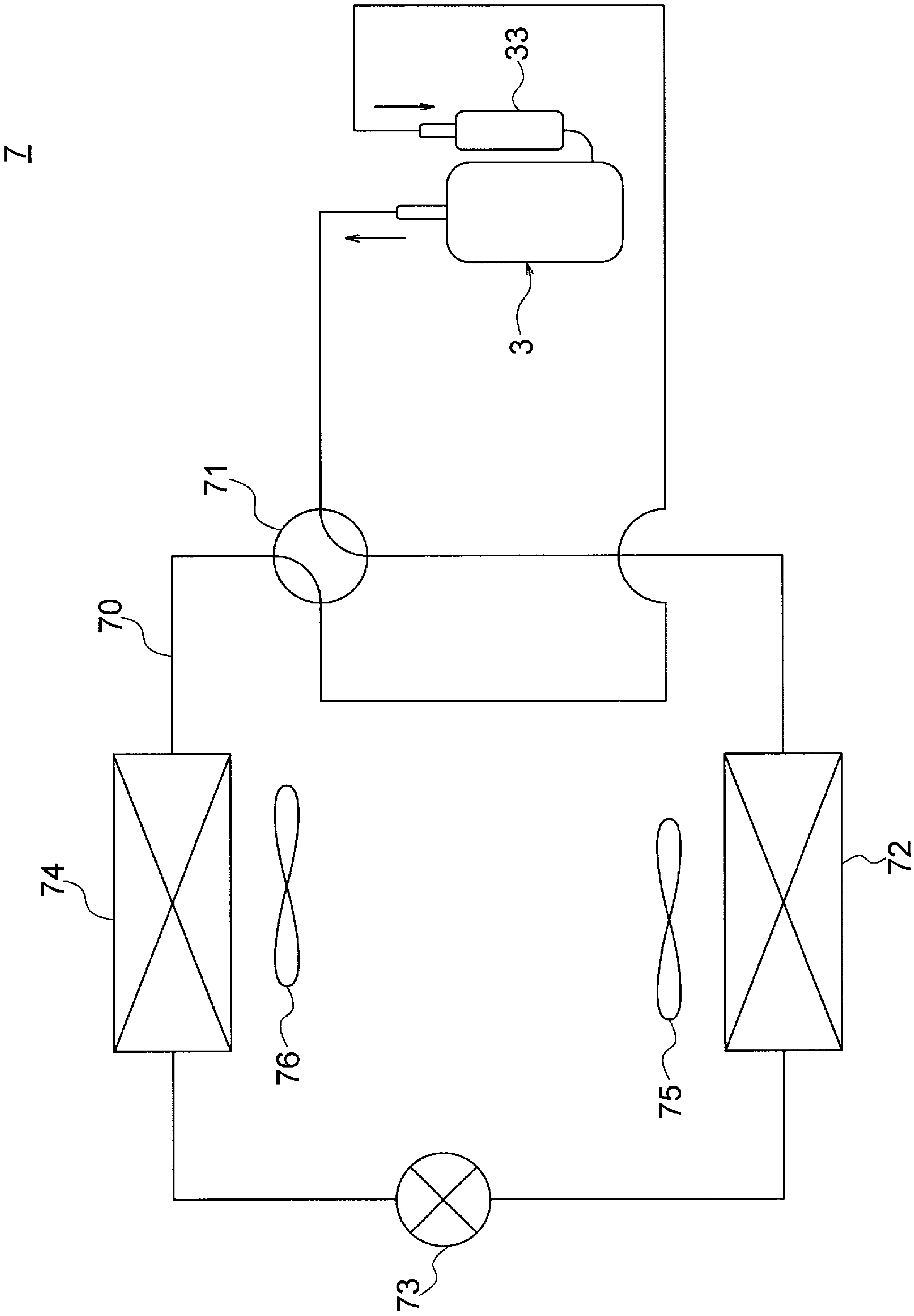
14B

FIG. 8



COMPRESSOR AND AIR CONDITIONER

CROSS REFERENCE TO RELATED APPLICATION

This application is a U.S. national stage application of International Patent Application No. PCT/JP2019/005004 filed on Feb. 13, 2019, the disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a compressor and an air conditioner.

BACKGROUND

A compressor for use in an air conditioner or the like includes a compression mechanism portion, a motor, and a rotation shaft connecting the compression mechanism portion and the motor. The rotation shaft is supported at one end thereof by a bearing portion provided in the compression mechanism portion (see, for example, Patent Reference 1).

PATENT REFERENCE

Patent Reference 1: Japanese Patent Application Publication No. 2005-248843 (see FIG. **1**)

In order to increase an output of a compressor, it is necessary to increase a stroke capacity of the compressor and to rotate a rotor at a high speed. In this case, however, an increased torque and an increased centrifugal force may cause the rotor to whirl, and thus vibration and noise of the compressor may increase. In addition, as a rotation speed increases, an iron loss in the rotor increases, and accordingly a temperature of the rotor rises. Thus, permanent magnets attached to the rotor may be demagnetized, and a sliding loss between the rotation shaft and the bearing portion may increase.

Therefore, it is required to reduce vibration and noise of the compressor and to suppress a temperature rise of the compressor.

SUMMARY

The present invention is made to solve the problem described above, and an object of the present invention is to reduce vibration and noise of a compressor and to suppress a temperature rise of the compressor.

A compressor according to an aspect of the present invention includes a motor, a compression mechanism portion driven by the motor, and a rotation shaft connecting the motor and the compression mechanism portion. The rotation shaft has a first shaft portion on an inner side in a radial direction about a rotation center of the rotation shaft, and has a second shaft portion on an outer side of the first shaft portion in the radial direction. The first shaft portion is composed of a material having a higher Young's modulus than that of cast iron, and having a higher thermal conductivity than that of cast iron.

According to the present invention, at least a part of the rotation shaft is composed of a material having a higher Young's modulus than that of cast iron and having a higher thermal conductivity than that of cast iron. Thus, vibration and noise of the compressor can be reduced, and a temperature rise of the compressor can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a longitudinal sectional view illustrating a compressor according to a first embodiment.

FIG. **2** is a cross sectional view illustrating a motor according to the first embodiment.

FIG. **3** is a longitudinal sectional view illustrating a compression mechanism portion according to the first embodiment.

FIG. **4** is a cross sectional view illustrating the compression mechanism portion according to the first embodiment.

FIG. **5** is a longitudinal sectional view illustrating a compressor according to a second embodiment.

FIG. **6** is a longitudinal sectional view illustrating a compression mechanism portion according to the second embodiment.

FIG. **7** is a longitudinal sectional view illustrating a compression mechanism portion according to a third embodiment.

FIG. **8** is a view illustrating a configuration of an air conditioner to which the compressor according to each embodiment is applicable.

DETAILED DESCRIPTION

Embodiments of the present invention will be described in detail with reference to the drawings. These embodiments are not intended to limit the present invention.

First Embodiment

(Configuration of Compressor)

FIG. **1** is a longitudinal sectional view illustrating a compressor **3** according to a first embodiment. The compressor **3** is a rotary compressor. The compressor **3** includes a compression mechanism portion **31**, a motor **6** that drives the compression mechanism portion **31**, a rotation shaft **10** connecting the compression mechanism portion **31** and the motor **6**, and a closed container **32** that accommodates these components. In this example, an axial direction of the rotation shaft **10** is a vertical direction, and the motor **6** is disposed above the compression mechanism portion **31**.

In the following description, a direction of an axis C**1** that is a rotation center of the rotation shaft **10** will be referred to as an "axial direction." A radial direction about the axis C**1** will be referred to as a "radial direction," and a circumferential direction (indicated by arrow R**1** in FIG. **2**) about the axis C**1** will be referred to as a circumferential direction. A sectional view in a plane parallel to the axis C**1** will be referred to as a longitudinal sectional view, and a sectional view in a plane perpendicular to the axis C**1** will be referred to as a cross sectional view.

(Configuration of Motor)

FIG. **2** is a cross sectional view illustrating the motor **6**. The motor **6** is a motor of a so-called inner rotor type, and includes a stator **5** and a rotor **4** rotatably disposed on the inner side of the stator **5**. A gap of, for example, 0.3 to 1.0 mm is formed between the rotor **4** and the stator **5**.

The rotor **4** includes a cylindrical rotor core **40** and permanent magnets **45** attached to the rotor core **40**. The rotor core **40** is formed by stacking a plurality of electromagnetic steel sheets in the axial direction and integrating the electromagnetic steel sheets by crimping or the like. The thickness of each electromagnetic steel sheet is 0.1 to 0.7 mm, and is 0.35 mm in this example. A shaft hole **44** is formed at the center of the rotor core **40** in the radial direction. The above described rotation shaft **10** is fixed to the shaft hole **44** by shrink fitting, press fitting, adhesion or the like.

A plurality of magnet insertion holes **41** in which the permanent magnets **45** are inserted are formed along the outer circumference of the rotor core **40**. The number of magnet insertion holes **41** is six in this example. The number of magnet insertion holes **41**, however, is not limited to six, and only needs to be two or more. One magnet insertion hole **41** corresponds to one magnetic pole, and a portion between each adjacent two of the magnet insertion holes **41** corresponds to an inter-pole portion. Each of the magnet insertion holes **41** has a V shape whose center portion in the circumferential direction projects inward in the radial direction.

Two permanent magnets **45** are inserted in each of the magnet insertion holes **41**. Each permanent magnet **45** has a width in the circumferential direction of the rotor core **40** and has a thickness in the radial direction. The thickness of each of the permanent magnets **45** is greater than or equal to 2.5 times a gap between the rotor **4** and the stator **5**, and is 2 mm, for example.

Each permanent magnet **45** is, for example, a rare earth magnet containing neodymium (Nd), iron (Fe), and boron (B) as main components. The permanent magnet **45** contains no heavy rare earth element such as dysprosium (Dy) or terbium (Tb), or contains 2 weight percent or less of the heavy rare earth element.

Each permanent magnet **45** is magnetized in the thickness direction. Two permanent magnets **45** inserted in the same magnet insertion hole **41** have the same magnetic poles on the outer side in the radial direction. The permanent magnets **45** inserted in adjacent magnet insertion holes **41** have opposite magnetic poles on the outer side in the radial direction. The shape of each magnet insertion hole **41** is not limited to the V shape. It is sufficient that at least one permanent magnet **45** is disposed in each magnet insertion hole **41**.

Flux barriers **42** serving as leakage magnetic flux reduction holes are formed at both ends of each magnet insertion hole **41** in the circumferential direction. A core portion between each flux barrier **42** and the outer circumference of the rotor core **40** is a thin portion so as to reduce leakage magnetic flux between adjacent magnetic poles.

An outer diameter Dr (FIG. **1**) of the rotor core **40** is smaller than or equal to an inner diameter Ds (FIG. **4**) of a cylinder chamber **26** described later. A length Lr (FIG. **1**) of the rotor core **40** in the axial direction is longer than the outer diameter Dr of the rotor core **40**. Accordingly, a torque of the motor **6** can be increased while reducing a centrifugal force of the rotor **4** in high-speed rotation.

End plates **47** and **48**, each of which is in the form of a disk, are fixed to both ends of the rotor **4** in the axial direction in order to prevent detachment of the permanent magnets **45** from the magnet insertion holes **41**. The end plates **47** and **48** are provided with balance weights for enhancing rotation balance of the rotor **4**.

In order to increase rigidity, the rotor **4** includes a cylindrical holding portion **46** covering the outer circumference of the rotor core **40**. The holding portion **46** is fixed to the outer circumference of the rotor core **40** by an adhesive agent, press fitting, shrink fitting, or cool fitting. The holding portion **46** is composed of, for example, carbon fiber reinforced plastic (CFRP), stainless steel, or a resin.

The stator **5** includes a stator core **50** and a coil **55** wound on the stator core **50**. The stator core **50** is formed by stacking a plurality of electromagnetic steel sheets in the axial direction and integrating the electromagnetic steel sheets by crimping or the like. The thickness of each electromagnetic steel sheet is 0.1 to 0.5 mm, and is 0.25 mm in this example.

The thickness of each electromagnetic steel sheet of the stator core **50** is preferably thinner than the thickness of each electromagnetic steel sheet of the rotor core **40**. In the stator **5**, an iron loss tends to be larger than that in the rotor **4**. A temperature rise of the stator **5** can be suppressed by using the thinner electromagnetic steel sheets.

The stator core **50** includes a yoke **51** having an annular shape about the axis C**1**, and a plurality of teeth **52** extending inward in the radial direction from the yoke **51**. The teeth **52** are arranged at regular intervals in the circumferential direction. The number of teeth **52** is nine in this example. The number of the teeth **52**, however, is not limited to nine, and only needs to be two or more. A slot **53** that is a space for accommodating the coil **55** is formed between each two of the teeth **52** adjacent to each other in the circumferential direction.

In this example, the stator core **50** has a configuration in which a plurality of split cores **5**A each including one tooth **52** are connected to one another in the circumferential direction. The number of split cores **5**A is equal to the number of teeth **52**. The split cores **5**A are connected to one another at connecting portions **51***a* disposed at end portions of the yoke **51** on the outer circumference side. In this regard, the stator core **50** is not limited to the configuration in which the split cores **5**A are connected.

An insulating portion **54** (FIG. **1**) composed of a resin such as polybutylene terephthalate (PBT) is provided between the core **50** and the coil **55**. The insulating portion **54** is formed by attaching a resin molded body to the stator core **50** or by molding the stator core **50** integrally with the resin.

The stator core **50** is incorporated in the closed container **32** (FIG. **1**) of the compressor **3** by shrink fitting, press fitting, welding or the like.

(Configuration of Compression Mechanism portion)

As illustrated in FIG. **1**, the compression mechanism portion **31** includes a cylinder **21** including a cylinder chamber **26**, a rolling piston **22** fixed to the rotation shaft **10**, a vane **25** (FIG. **4**) dividing the inside of the cylinder chamber **26** into a suction side and a compression side, and an upper frame **23** and a lower frame **24** that close ends of the cylinder chamber **26** in the axial direction. An upper discharge muffler **27** and a lower discharge muffler **28** are attached to the upper frame **23** and the lower frame **24**, respectively.

The closed container **32** is a cylindrical container formed by drawing a steel sheet. The stator **5** of the motor **6** is incorporated inside the closed container **32** by shrink fitting, press fitting, welding or the like. In the bottom portion of the closed container **32**, refrigerating machine oil as lubricant for lubricating sliding portions of the compression mechanism portion **31** is stored.

An upper portion of the closed container **32** is provided with a discharge pipe **35** through which refrigerant is discharged to the outside, and a terminal **36** for supplying electric power to the coil **55** of the stator **5**. An accumulator **33** that stores refrigerant gas is fixed to the outside of the closed container **32** via a fixing portion **37**.

FIG. **3** is a longitudinal sectional view illustrating the compression mechanism portion **31**. FIG. **4** is a cross sectional view illustrating the compression mechanism portion **31** taken along line IV-IV in FIG. **1**. The cylinder **21** of the compression mechanism portion **31** includes a cylinder chamber **26** having a cylindrical shape about the axis C**1**.

The rotation shaft **10** includes an eccentric shaft portion **14** located inside the cylinder chamber **26**. The eccentric shaft portion **14** includes a cylindrical part having a center axis which is eccentric with respect to the axis C1.

The rolling piston **22** having a ring shape is fitted onto the outer circumference of the eccentric shaft portion **14**. When the rotation shaft **10** rotates, the eccentric shaft portion **14** and the rolling piston **22** rotate about the center axis which is eccentric with respect to the axis C1 inside the cylinder chamber **26**.

A portion of the rotation shaft **10** on the motor **6** side with respect to the eccentric shaft portion **14** will be referred to as a main shaft portion **101**. A portion of the rotation shaft **10** on a side opposite to the main shaft portion **101** with respect to the eccentric shaft portion **14** will be referred to as an auxiliary shaft portion **102**. In this example, the main shaft portion **101** is located at an upper side, and the auxiliary shaft portion **102** is located at a lower side. Centers of the main shaft portion **101** and the auxiliary shaft portion **102** are located on the axis C1. A center hole **13** is formed along the axis C1 at the center of the rotation shaft **10**.

The upper frame **23** includes a flat plate portion **23***a* that closes the upper end of the cylinder chamber **26**, and a bearing portion **23***b* rotatably supporting the main shaft portion **101** of the rotation shaft **10**. The bearing portion **23***b* is a slide bearing. The upper frame **23** is composed of iron such as cast iron, and fixed to the upper surface of the cylinder **21** using, for example, bolts or the like.

Refrigerating machine oil stored in the bottom portion of the closed container **32** is supplied to between the bearing portion **23***b* of the upper frame **23** and the main shaft portion **101** through the center hole **13** and an oil supply path **15** of the rotation shaft **10**. The main shaft portion **101** is rotatably supported by the bearing portion **23***b* with fluid lubrication of an oil film of the refrigerating machine oil.

The lower frame **24** includes a flat plate portion **24***a* that closes the lower end of the cylinder chamber **26**, and a bearing portion **24***b* rotatably supporting the auxiliary shaft portion **102** of the rotation shaft **10**. The bearing portion **24***b* is a slide bearing. The lower frame **24** is composed of iron such as cast iron, and fixed to the lower surface of the cylinder **21** using, for example, bolts or the like.

The refrigerating machine oil stored in the bottom portion of the closed container **32** is supplied to between the bearing portion **24***b* of the lower frame **24** and the auxiliary shaft portion **102** through the center hole **13** and an oil supply path **16** of the rotation shaft **10**. The auxiliary shaft portion **102** is rotatably supported by the bearing portion **24***b* with fluid lubrication of an oil film of the refrigerating machine oil.

As illustrated in FIG. **4**, the cylinder **21** includes a vane trench **21***a* extending in the radial direction about the axis C1. One end of the vane trench **21***a* communicates with the cylinder chamber **26**, and the other end of the vane trench **21***a* communicates with a back pressure chamber **21***b*. The vane **25** is inserted in the vane trench **21***a*. The vane **25** is capable of reciprocating in the vane trench **21***a*. The back pressure chamber **21***b* is provided with a spring which pushes the vane **25** from the vane trench **21***a* into the cylinder chamber **26** so that an end of the vane **25** is brought into contact with the outer circumferential surface of the rolling piston **22**.

The vane **25** partitions a space formed by the inner circumferential surface of the cylinder chamber **26** and the outer circumferential surface of the rolling piston **22**, into two operation chambers. One of the two operation chambers that communicates with a suction port **29** functions as a suction chamber **26***a* into which low-pressure refrigerant gas is sucked, and the other operation chamber functions as a compression chamber **26***b* that compresses the refrigerant. The cylinder **21** has the suction port **29** through which the refrigerant gas is sucked into the cylinder chamber **26** from the outside of the closed container **32**. The suction port **29** communicates with the suction chamber **26***a* in the cylinder chamber **26**.

The suction port **29** is connected to a suction pipe **34** of the accumulator **33** (FIG. **1**). The compressor **3** is supplied with a mixture of low-pressure refrigerant gas and liquid refrigerant from a refrigerant circuit of an air conditioner **7**. When the liquid refrigerant flows into the compression mechanism portion **31** and is compressed therein, it may cause a malfunction of the compression mechanism portion **31**. Thus, the liquid refrigerant and the refrigerant gas are separated in the accumulator **33**, and only the refrigerant gas is supplied to the compression mechanism portion **31**.

The upper frame **23** has an outlet port through which the refrigerant gas compressed in the compression chamber **26***b* (FIG. **4**) of the cylinder chamber **26** is discharged to the outside of the cylinder chamber **26**. The outlet port is provided with a discharge valve. The discharge valve opens when the pressure of the refrigerant gas compressed in the compression chamber **26***b* of the cylinder chamber **26** reaches a specified pressure or more, and the refrigerant gas is discharged into the closed container **32**.

The refrigerant gas discharged into the closed container **32** from the cylinder chamber **26** flows to an upper portion of the closed container **32**. The refrigerant gas flows upward through the gap between the rotor **4** and the stator **5** of the motor **6** and a gap between the stator **5** and the inner circumferential surface of the closed container **32**, and is sent to the outside of the closed container **32** through the discharge pipe **35**.

For example, R410A, R407C, and R22 or the like is used as the refrigerant. From the viewpoint of preventing global warming, it is preferable to use refrigerant whose global warming potential (GWP) is low.

The length Lr of the rotor core **40** in the axial direction is preferably longer than or equal to the length Ls of the cylinder **21** of the compression mechanism portion **31** in the axial direction, and more preferably longer than or equal to twice the length Ls of the cylinder **21** in the axial direction. As the length Lr of the rotor core **40** in the axial direction increases, the length of each permanent magnet **45** in the axial direction increases and a magnetic force increases. Accordingly, a torque increases.

(Configuration of Rotation Shaft)

The rotation shaft **10** includes a first shaft portion **11** and a second shaft portion **12**. The first shaft portion is located on the inner side in the radial direction, and the second shaft portion **12** is located on the outer side in the radial direction. Each of the first shaft portion **11** and the second shaft portion **12** is formed to extend from one end to the other end of the rotation shaft **10** in the axial direction, that is, from the lower end to the upper end in FIG. **1**.

The first shaft portion **11** is composed of a material whose Young's modulus and thermal conductivity are higher than those of cast iron. The material whose Young's modulus and thermal conductivity are higher than those of cast iron is, for example, carbon fiber reinforced plastic (CFRP). On the other hand, the second shaft portion **12** is composed of iron, more specifically, cast iron.

The carbon fiber reinforced plastic preferably includes pitch carbon fibers having a fiber length of 50 μm to 3 μm and a thermoplastic resin such as polyethylene terephthalate

(PET) or polybutylene terephthalate (PBT). The pitch carbon fibers are preferably of an ultra-high modulus type.

The Young's modulus of cast iron is 100 to 170 [GPa]. The Young's modulus of carbon fiber reinforced plastic is 300 to 900 [GPa]. That is, the Young's modulus of carbon fiber reinforced plastic is three to five times the Young's modulus of cast iron.

The thermal conductivity of cast iron is 40 to 50 [W/mK]. The thermal conductivity of carbon fiber reinforced plastic is 150 to 900 [W/mK]. That is, the thermal conductivity of carbon fiber reinforced plastic is 3 to 18 times the thermal conductivity of cast iron.

The rotation shaft **10** having the configuration described above is made by inserting the first shaft portion **11** composed of carbon fiber reinforced plastic into the second shaft portion **12** composed of a casting of cast iron so that the first shaft portion **11** serves as a core rod.

The cast iron is a material used for a rotation shaft of a general compressor. It can be said that the first shaft portion **11** of the rotation shaft **10** is composed of a material whose Young's modulus and thermal conductivity are higher than those of the material used for the rotating shaft of the general compressor. On the other hand, it can be said that the second shaft portion **12** is composed of a material similar to the material used for the rotation shaft of the general compressor.

Since the first shaft portion **11** is composed of the material whose Young's modulus and thermal conductivity are higher than those of cast iron, deflection of the rotation shaft **10** can be suppressed and vibration and noise can be reduced. In addition, heat due to an iron loss in the rotor **4** and a sliding loss can be dissipated through the rotation shaft **10**, and a temperature rise of the rotor **4** can be suppressed.

In a cross section perpendicular to the axial direction, an outer diameter D**1** of the first shaft portion **11** is smaller than 90% of an outer diameter D**0** of the rotation shaft **10** ($D1<0.9\times D0$). Since the thickness of the second shaft portion **12** is not excessively thin, the second shaft portion **12** can be prevented from separating from the first shaft portion **11**.

(Operation of Compressor)

Next, an operation of the compressor **3** will be described. When a current is supplied to the coil **55** of the stator **5** via the terminal **36**, a magnetic field generated by the current of the coil **55** and a magnetic field of the permanent magnets **45** of the rotor **4** cause an attraction force and a repulsive force between the stator **5** and the rotor **4** so that the rotor **4** rotates. Accordingly, the rotation shaft **10** fixed to the rotor **4** also rotates.

In the cylinder chamber **26**, the eccentric shaft portion **14** of the rotation shaft **10** and the rolling piston **22** attached to the eccentric shaft portion **14** rotate in a direction indicated by an arrow A in FIG. **4** about the axis eccentric with respect to the axis C**1**. The eccentric rotation of the eccentric shaft portion **14** and the rolling piston **22** in the cylinder chamber **26** causes the operation chamber communicating with the suction port **29** to function as the suction chamber **26***a* to suck low-pressure refrigerant gas.

The refrigerant gas in the accumulator **33** is supplied to the suction chamber **26***a* of the cylinder chamber **26** through the suction pipe **34**. The suction chamber **26***a* supplied with the refrigerant gas moves in the cylinder chamber **26** by the eccentric rotation of the eccentric shaft portion **14** and the rolling piston **22**, and communication with the suction port **29** is interrupted. Thereafter, the suction chamber **26***a* functions as the compression chamber **26***b*. The eccentric rotation of the eccentric shaft portion **14** and the rolling piston **22** reduces the volume of the compression chamber **26***b* so that the refrigerant gas is compressed.

As the eccentric rotation of the eccentric shaft portion **14** and the rolling piston **22** proceeds, the compression chamber **26***b* comes to communicate with the outlet port. Accordingly, the high-pressure refrigerant gas in the compression chamber **26***b* is discharged into the closed container **32** through the outlet port. When the eccentric rotation of the eccentric shaft portion **14** and the rolling piston **22** further proceeds, communication of the compression chamber **26***b* with the outlet port is interrupted and the compression chamber **26***b* communicates with the suction port **29** again, and thereafter the compression chamber **26***b* functions as the suction chamber **26***a*.

The refrigerant compressed in the cylinder chamber **26** passes through discharge mufflers **27** and **28**, then passes through the gap between the rotor **4** and the stator **5** and the gap between the stator **5** and the closed container **32**, and then flows upward in the closed container **32**. The refrigerant flowing upward in the closed container **32** is discharged through the discharge pipe **35**, and is sent to the refrigerant circuit in the air conditioner **7** (FIG. **8**).

(Action)

In a case where the rotor **4** is eccentrically attached to the rotation shaft **10** because of a variation in assembling or the like, a gap between the rotor **4** and the stator **5** may be non-uniform in the circumferential direction, and a magnetic attraction force may occur between the rotor **4** and the stator **5**. If the rotor **4** has an imbalance in a mass distribution, a large centrifugal force may be exerted on the rotor **4**. These forces cause whirling of the rotor **4** in high-speed operation.

Since the rotation shaft **10** is supported at an end thereof by the bearing portions **23***b* and **24***b* of the compression mechanism portion **31**, a force is exerted on the rotation shaft **10** so as to deflect the rotation shaft **10** about the bearing portions **23***b* and **24***b* as a fulcrum.

In the first embodiment, the first shaft portion **11** of the rotation shaft **10** is composed of a material having a higher Young's modulus than that of cast iron. Thus, rigidity of the rotation shaft **10** can be increased, and deflection of the rotation shaft **10** due to the magnetic attraction force and the centrifugal force can be suppressed.

Accordingly, even when the rotor **4** is rotated at a high speed of, for example, 7800 rpm or more, vibration and noise of the compressor **3** can be reduced. That is, the highly-reliable and high-power compressor **3** can be obtained.

By increasing the rigidity of the rotation shaft **10**, the outer diameter of the rotation shaft **10** can be reduced, and the capacity of the cylinder chamber **26** can be increased. The reduction of the outer diameter of the rotation shaft **10** reduces the sliding loss between the rotation shaft **10** and the bearing portions **23***b* and **24***b*, and thus a temperature rise of the compressor **3** can be suppressed.

While the rotor **4** rotates at high speed, heat is generated by an iron loss in the rotor core **40**, an eddy-current loss in the permanent magnets **45**, and the sliding loss (friction) between the bearing portions **23***b* and **24***b* and the rotation shaft **10**. Since the first shaft portion **11** of the rotation shaft **10** is composed of a material having a higher thermal conductivity than that of cast iron, heat is dissipated through the rotation shaft **10**, and the temperature rise of the compressor **3** can be suppressed. Meanwhile, heat dissipated from the rotation shaft is released to the outside through the discharge pipe **35** together with the refrigerant.

While the rotor **4** rotates, heat is generated by the eddy-current loss in the permanent magnets **45**, but is dissipated through the rotation shaft **10** so that a temperature rise of the permanent magnets **45** can be suppressed. The rare earth magnet constituting the permanent magnets **45** is likely to be demagnetized as the temperature increases, but the demagnetization of the permanent magnets **45** can be suppressed by suppressing the temperature rise of the permanent magnets **45**.

Since the second shaft portion **12** of the rotation shaft **10** is composed of iron such as cast iron, an excellent sliding characteristic between the rotation shaft **10** and the bearing portions **23***b* and **24***b* composed of iron such as cast iron can be maintained. That is, rigidity of the rotation shaft **10** can be increased without impairing the sliding characteristic between the rotation shaft **10** and the bearing portions **23***b* and **24***b*.

In a cross section perpendicular to the axial direction, the outer diameter D1 of the first shaft portion **11** is smaller than 90% of the outer diameter D0 of the rotation shaft **10** ($D1<0.9\times D0$). Since the thickness of the second shaft portion **12** is not excessively thin, the second shaft portion **12** can be prevented from separating from the first shaft portion **11**.

In addition, deflection of the rotation shaft **10** is suppressed as described above, and thus, even in the case where the outer diameter of the rotation shaft **10** is made small, adhesive wear and galling (scuffing) of the rotation shaft **10** can be suppressed. That is, a mechanical loss in the compressor can be reduced, and the highly efficient and small-sized compressor **3** can be obtained.

As described above, the outer diameter Dr of the rotor core **40** is smaller than or equal to the inner diameter Ds of the cylinder chamber **26** (FIG. **4**). Since the outer diameter Dr of the rotor core **40** is not excessively large as described above, a centrifugal force during high-speed rotation of the rotor **4** can be reduced. The length Lr of the rotor core **40** in the axial direction is longer than the outer diameter Dr of the rotor core **40**. As the length Lr of the rotor core **40** increases, the length of each permanent magnet **45** increases. Thus, a magnetic force of the permanent magnets **45** increases, and a torque increases. Accordingly, a sufficient torque corresponding to a stroke volume of the compression mechanism portion **31** can be generated. As a result, the motor **6** can be driven at high speed with high torque.

As described above, the length Lr of the rotor core **40** in the axial direction is preferably longer than or equal to the length Ls of the cylinder **21** of the compression mechanism portion **31** in the axial direction, and more preferably longer than or equal to twice the length Ls of the cylinder **21** in the axial direction. As the length of the rotor core **40** in the axial direction increases, the length of each permanent magnets in the axial direction increases and a magnetic force increases. Thus, a torque increases. As a result, even when a compression load increases as in a case where the stroke volume of the compression mechanism portion **31** is, for example, 200 cc or more, a torque corresponding to the compression load can be generated. In addition, a load variation of the compression mechanism portion **31** due to a torque insufficiency of the motor **1** can be suppressed.

As described above, the rotor **4** includes the holding portion **46** covering the outer circumference of the rotor core **40**. The holding portion **46** is composed of, for example, carbon fiber reinforced plastic, stainless steel, or a resin. Since the holding portion **46** is provided, rigidity of the rotor **4** can be increased. Accordingly, the rotor **4** can rotate at high speed without degradation of performance of the motor **6**, and an output of the motor **6** can be increased.

The holding portion **46** is preferably composed of a non-magnetic material. Specifically, the holding portion **46** is preferably composed of nonmagnetic carbon fiber reinforced plastic, nonmagnetic stainless steel, or a nonmagnetic resin. When the holding portion **46** is composed of the non-magnetic material, leakage magnetic flux between adjacent magnetic poles of the rotor **4** can be reduced, and a magnetic force of the rotor **4** can be further increased. In addition, an increase of an eddy current in the rotor **4** can be suppressed.

A linear expansion coefficient of the holding portion **46** is preferably smaller than a linear expansion coefficient of the rotor core **40**. For example, in a case where the holding portion **46** is composed of carbon fiber reinforced plastic, the linear expansion coefficient of the holding portion **46** is smaller than a linear expansion coefficient of electromagnetic steel sheets constituting the rotor core **40**. Accordingly, a change in the gap between the rotor **4** and the stator **5** with temperature can be suppressed.

Since the carbon fiber reinforced plastic has high strength, the holding portion **46** can be made thin when the holding portion **46** is composed of carbon fiber reinforced plastic. Accordingly, the gap between the rotor **4** and the stator **5** can be reduced, and the magnetic force of the permanent magnets **45** can be effectively used. As a result, the rotation speed of the rotor **4** can be increased, and motor efficiently can be enhanced.

Advantages of Embodiment

As described above, the compressor **3** according to the first embodiment includes the motor **6**, the compression mechanism portion **31** driven by the motor **6**, and the rotation shaft **10** connecting the motor **6** and the compression mechanism portion **31**. The first shaft portion **11** of the rotation shaft **10** is composed of a material having a higher Young's modulus than that of cast iron, and having a higher thermal conductivity than that of cast iron. Thus, rigidity of the rotation shaft **10** can be increased and deflection of the rotation shaft **10** can be suppressed. Thus, vibration and noise can be reduced. Further, due to the heat dissipation effect through the rotation shaft **10**, a temperature rise of the compressor **3** can be suppressed. As a result, the motor **6** can be driven at high speed with high torque, and an output of the compressor **3** can be increased.

In particular, since the first shaft portion **11** is composed of carbon fiber reinforced plastic, rigidity and heat dissipation property of the rotation shaft **10** can be further enhanced, and the output of the compressor **3** can be further increased.

In addition, the rotation shaft **10** includes the eccentric shaft portion **14** which is eccentric with respect to the axis **C1**. The compression mechanism portion **31** includes the rolling piston **22** attached to the eccentric shaft portion **14**, and the cylinder including the cylinder chamber **26** in which the eccentric shaft portion **14** and the rolling piston **22** are disposed. Thus, rotation of the rotation shaft **10** causes eccentric rotation of the eccentric shaft portion **14** and the rolling piston **22** in the cylinder chamber **26** so as to compress the refrigerant.

The rotation shaft **10** includes the first shaft portion **11** on the inner side in the radial direction, and the second shaft portion **12** on the outer side of the first shaft portion **11** in the radial direction. The first shaft portion **11** is made of a material, such as carbon fiber reinforced plastic, having a higher Young's modulus than that of cast iron and a higher thermal conductivity than that of cast iron. Thus, rigidity and heat dissipation property of the rotation shaft **10** can be enhanced

In addition, since the second shaft portion **12** is composed of iron, more specifically, cast iron, an excellent sliding characteristic between the rotation shaft **10** and the bearing portions **23***b* and **24***b* can be obtained, and a sliding loss can be suppressed.

Since the first shaft portion **11** and the second shaft portion **12** extend from one end to the other end of the rotation shaft **10** in the axial direction, it is not necessary to provide the rotation shaft **10** with a joint portion at which different materials are joined in the axial direction. Accordingly, rigidity of the entire rotation shaft **10** can be increased.

Since the rotor **4** includes the rotor core **40** and the permanent magnets **45** and the permanent magnets **45** are rare earth magnets, a high torque can be generated.

Since the rotor **4** includes the holding portion **46** that holds the rotor core **40** from the outer side in the radial direction, the rigidity of the rotor **4** can be increased, and the rotation speed of the rotor **4** can be increased.

In addition, since the holding portion **46** is composed of a non-magnetic material, leakage magnetic flux between adjacent magnetic poles of the rotor **4** can be reduced. As a result, a magnetic force of the permanent magnets **45** of the rotor **4** can be further increased, and a higher torque can be generated.

Second Embodiment

FIG. **5** is a longitudinal sectional view illustrating a compressor **3**A according to a second embodiment. FIG. **6** is a longitudinal sectional view illustrating a compression mechanism portion **31**A of the compressor **3**A according to the second embodiment. The compressor **3**A of the second embodiment is different from the compressor **3** of the first embodiment in the configuration of a rotation shaft **10**A.

In the rotation shaft **10**A of the second embodiment, each of a main shaft portion **101** and an auxiliary shaft portion **102** is composed of a material whose Young's modulus and thermal conductivity are higher than those of cast iron. In addition, a center portion **14**A of an eccentric shaft portion **14**, that is, a portion having the same sectional shape as that of each of the main shaft portion **101** and the auxiliary shaft portion **102**, is composed of a material whose Young's modulus and thermal conductivity are higher than those of cast iron.

The main shaft portion **101** and the auxiliary shaft portion **102** of the rotation shaft **10**A and the center portion **14**A of the eccentric shaft portion **14** are composed of, for example, carbon fiber reinforced plastic. A portion of the eccentric shaft portion **14** except for the center portion **14**A is composed of iron such as cast iron.

The rotation shaft **10**A having the configuration described above is made by inserting a shaft portion composed of, for example, carbon fiber reinforced plastic into the eccentric shaft portion **14** composed of a casting of cast iron so that the shaft portion serves as a core rod.

In the second embodiment, the main shaft portion **101** and the auxiliary shaft portion **102** of the rotation shaft **10**A and the center portion **14**A of the eccentric shaft portion **14** are composed of the material whose Young's modulus and thermal conductivity are higher than those of cast iron, and thus rigidity and heat dissipation property of the rotation shaft **10**A can be further enhanced. As a result, vibration and noise of the compressor **3**A can be reduced, a temperature rise of the compressor **3**A can be suppressed, and an output of the compressor **3**A can be further increased.

Third Embodiment

FIG. **7** is a longitudinal sectional view illustrating a compression mechanism portion **31**B of a compressor **3**B according to a third embodiment. The compressor **3**B of the third embodiment is different from the compressor **3** of the first embodiment in the configuration of a rotation shaft **10**B.

In the third embodiment, the entire rotation shaft **10**B including a main shaft portion **101**, an auxiliary shaft portion **102**, and an eccentric shaft portion **14** is composed of a material whose Young's modulus and thermal conductivity are higher than those of cast iron. More specifically, the entire rotation shaft **10**B is composed of, for example, carbon fiber reinforced plastic.

The rotation shaft **10**B described above is made by forming a molded body including the main shaft portion **101**, the auxiliary shaft portion **102**, and the eccentric shaft portion **14** using carbon fiber reinforced plastic by injection molding, and polishing the molded body to form sliding surfaces that slide with the bearing portions **23***b* and **24***b*.

In the third embodiment, the entire rotation shaft **10**B is composed of the material whose Young's modulus and thermal conductivity are higher than those of cast iron, and thus rigidity and heat dissipation property of the rotation shaft **10**B can be further enhanced. As a result, vibration and noise of the compressor **3**B can be reduced, a temperature rise of the compressor **3**B can be suppressed, and an output of the compressor **3**B can be further increased.

In the first through third embodiments described above, the entire rotation shaft **10** (**10**A, **10**B) from one end to the other end in the axial direction is composed of the material whose Young's modulus and thermal conductivity are higher than those of cast iron. However, it is sufficient that at least a part of the rotation shaft **10** (**10**A, **10**B) located inside the compression mechanism portion **31** (**31**A, **31**B) is composed of the material whose Young's modulus and thermal conductivity are higher than those of cast iron.

(Air Conditioner)

Next, an air conditioner **7** (also referred to as a refrigeration air conditioning apparatus) to which the compressor **3** of each of the embodiments described above is applicable. FIG. **8** is a view illustrating a configuration of the air conditioner **7**. The air conditioner **7** illustrated in FIG. **8** includes the compressor **3** of the first embodiment, a four-way valve **71** as a switching valve, a condenser **72**, a decompressor **73**, an evaporator **74**, and a refrigerant pipe **70**. The compressor **3**, the condenser **72**, the decompressor **73**, and the evaporator **74** are connected by the refrigerant pipe **70**, and constitute a refrigerant circuit. The compressor **3** includes an outdoor fan **75** facing the condenser **72**, and an indoor fan **76** facing the evaporator **74**.

An operation of the air conditioner **7** is as follows. The compressor **3** compresses sucked refrigerant and sends the compressed refrigerant as high-temperature and high-pressure gas refrigerant. The four-way valve **71** is configured to switch a flow direction of the refrigerant, and causes the refrigerant sent from the compressor **3** to flow into the condenser **72** as illustrated in FIG. **8** in a cooling operation. The condenser **72** performs heat exchange between the refrigerant sent from the compressor **3** and outdoor air sent by the outdoor fan **75**, condenses the refrigerant, and sends the condensed refrigerant as liquid refrigerant. The decompressor **73** expands the liquid refrigerant sent from the condenser **72** and sends the refrigerant as low-temperature and low-pressure liquid refrigerant.

The evaporator **74** performs heat exchange between the low-temperature and low-pressure liquid refrigerant sent from the decompressor **73** and indoor air, evaporates (vaporizes) the refrigerant, and sends the refrigerant as gas refrigerant. Air from which heat is taken in the evaporator **74** is supplied to a room that is space to be air-conditioned, by the indoor fan **76**.

In a heating operation, the four-way valve **71** causes the refrigerant sent from the compressor **3** to flow into the evaporator **74**. In this case, the evaporator **74** functions as a condenser, and the condenser **72** functions as an evaporator.

As described in the first embodiment, the compressor **3** of the air conditioner **7** reduces vibration and noise and achieves high output by suppression of the temperature rise. Accordingly, quietness of the air conditioner **7** can be enhanced, and operation efficiency of the air conditioner **7** can be enhanced.

The compressor of the first embodiment may be replaced by the compressor of the second or third embodiment. Components except the compressor **3** in the air conditioner **7** are not limited to those used in the configurations described above.

Although preferred embodiments of the present invention have been specifically described above, the present invention is not limited to these embodiments, and various improvements and modifications may be made without departing from the scope of the invention.

What is claimed is:

1. A compressor comprising:

a motor;

a compression mechanism driven by the motor; and

a rotation shaft connecting the motor and the compression mechanism, the rotation shaft having an eccentric shaft portion which is eccentric with respect to a rotation center of the rotation shaft,

wherein the compression mechanism has a rolling piston attached to the eccentric shaft portion, a cylinder chamber in which the eccentric shaft portion and the rolling piston are disposed, and a bearing portion supporting the rotation shaft,

wherein the motor has a rotor fixed to the rotation shaft,

wherein an outer diameter Dr of the rotor in a radial direction about the rotation center of the rotation shaft and an inner diameter Ds of the cylinder chamber in the radial direction satisfy $Dr<Ds$,

wherein the rotation shaft has a first shaft portion on an inner side in a radial direction about a rotation center of the rotation shaft, and has a second shaft portion on an outer side of the first shaft portion in the radial direction, the first shaft portion and the second shaft portion being different from each other in material,

wherein the first shaft portion is composed of a carbon fiber reinforced plastic including pitch carbon fibers having a fiber length of 50 μm to 3 μm and a thermoplastic resin,

wherein the carbon fiber reinforced plastic having a range of a higher Young's modulus between 300 GPa to 900 GPa than a range of a Young's modulus of cast iron and having a higher thermal conductivity between 150 W/mk to 900 W/mk than a range of a thermal conductivity of cast iron,

wherein the second shaft portion is composed of a cast iron, and

wherein each of the first shaft and the second shaft portion extends from one end to the other end of the rotation shaft in an axial direction of the rotation shaft.

2. The compressor according to claim **1**, wherein at least a part of the rotation shaft is composed of carbon fiber reinforced plastic.

3. The compressor according to claim **1**, wherein when D**0** represents an outer diameter of the rotation shaft in the radial direction and D**1** represents an outer diameter of the first shaft portion in the radial direction, $D1<0.9\times D0$ is satisfied.

4. The compressor according to claim **1**, wherein the second shaft portion is composed of iron.

5. The compressor according to claim **4**, wherein a length of the rotor in an axial direction of the rotation shaft is longer than or equal to a length of the cylinder in the axial direction.

6. The compressor according to claim **4**, wherein an outer diameter of the rotor is smaller than a length of the rotor in an axial direction of the rotation shaft.

7. The compressor according to claim **1**, wherein the rotor has a rotor core and a permanent magnet attached to the rotor core.

8. The compressor according to claim **7**, wherein the permanent magnet is a rare earth magnet.

9. The compressor according to claim **7**, wherein the rotor has a holding portion that holds the rotor core from an outer side in a radial direction about the rotation center of the rotation shaft.

10. The compressor according to claim **9**, wherein the holding portion is composed of carbon fiber reinforced plastic, stainless steel, or a resin.

11. The compressor according to claim **9**, wherein the holding portion is composed of a non-magnetic material.

12. The compressor according to claim **1**, wherein the motor is disposed above the compression mechanism.

13. An air conditioner comprising:

the compressor according to claim **1**;

a condenser to condense refrigerant sent from the compressor;

a decompressor to decompress the refrigerant condensed by the condenser; and

an evaporator to evaporate the refrigerant decompressed by the decompressor.

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